represented by very few specimens only, but there are also exceptions ($v = 4$ in *aurantium* and *capensis*); very variable species often are composed of geographical races much differing in size.

The most common cowrie species is *annulus* which was represented by 11% of our 94923 specimens; it is followed by *moneta* and *isabella* (5.5 and over 4% respectively); *caputserpentis, carneola, erosa, errones, helvola, lynx,* and *arabica* follow with less than 4 to 3% each and after a distinct gap the series with less than 2% begins with *vredenburgi, asellus, gracilis* and *tigris.*

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Dimorphism and Monstrosities in Cowrie Radulae

BY

FRANZ ALFRED SCHILDER

AND

MARIA SCHILDER

University of Halle, German Democratic Republic

(14 Text figures)

IT IS TO BE REGRETTED that most authors are satisfied with the examination of only one or very few radulae of each cowrie species; they publish one drawing of each species and fail to discuss obvious differences from drawings by earlier authors. Thus the individual variation of radulae continues to be unknown though its range in size and shape seems to be not smaller than that of the shells.

During the past few years we have accumulated over 6000 microscope slides with radulae of cowries obtained chiefly from Kenya (SCHILDER & SCHILDER, 1963b), Fiji (SCHILDER & SCHILDER, 1964), and Queensland (SCHILDER, SCHILDER & HOUSTON, 1964), but also from many other areas. The quantitative results of our counting the rows and measuring the width of the median tooth and the length of the radula ribbon have been discussed in SCHILDER & SCHILDER, 1963a, in which paper may be found also references to our earlier papers on the same subject. The qualitative results concerning the features of typical radulae of almost all living cowrie species will be published in another paper. The present paper will show that in several species there is a dimorphism in the shape of radular teeth which cannot be explained as sexual difference only. We shall add drawings of some odd monstrosities which we observed by chance among our 6000 radulae: surely, careful examination of the almost five million teeth preserved in our slides would reveal far more pathological deformations.

DIMORPHISM

SCHILDER & CERNOHORSKY (1965, figs. 1 - 4) have shown that there are differences in the shape of the radular teeth of *Purpuradusta hammondae* (IREDALE) and *P. raysummersi* SCHILDER: in both there is a radula with a large, rather elongate median and strong laterals[1] with reduced

[1] We follow VAYSSIÈRE in calling the marginals "laterals" so that one can abbreviate the median, admedian and the two laterals simply by *m, a,* l_1 and l_2; in the figures we draw these teeth by ————, – – – –, ... , and again ———— respectively, so that misunderstanding the uniform lines belonging to different teeth will be avoided.

denticles at the sides of the central cusp (Figures 1, 3) and a radula with a smaller, rather transverse median and slender laterals with three distinct cusps (Figures 2, 4); we thought these differences to be, possibly, sexual.

An analogous dimorphism exists in *Purpuradusta fimbriata* (GMELIN), collected in Kenya and Natal by R. S. Benton: the median is large and about square in males, smaller and transversely rectangular in females (the average length is 100% and 83% of breadth respectively); the laterals are much stronger and broader in males than in females, their marginal denticles bordering the central cusp become far more frequently obsolete in males than in females, but all qualitative characters often overlap, as do the quantitative characters of sexes indicated by SCHILDER & SCHILDER 1963b (p. 109, table 2).

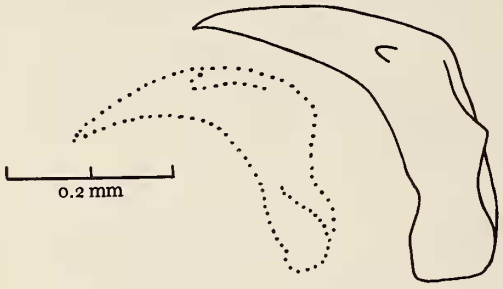

Figure 1

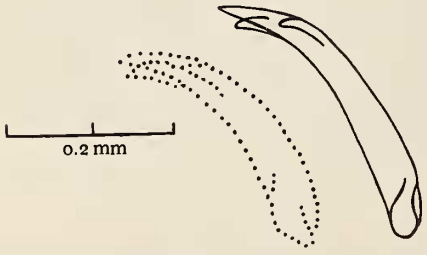

Figure 2

Similar differences in the laterals have been observed in the three species of the genus *Staphylaea* JOUSSEAUME: the differences in shape are so striking that one would never believe that the specimens belong to the same species. There is a broad hook-shaped type recalling the laterals of many other cowrie species, but with the marginal denticles mostly obsolete and placed far from the strong central cusp; the more frequent slender type is

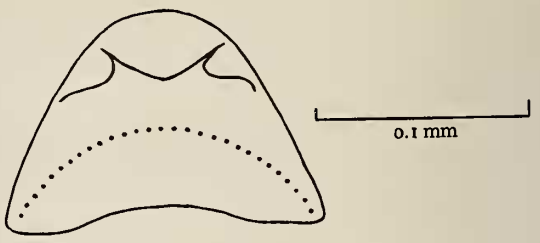

Figure 3

less curved and exhibits three distinct, rather equal lobes at its top. The hook-shaped type is shown in Figure 1, the slender type in Figure 2: both figures represent *St. limacina* (LAMARCK) from Shimoni, Kenya; Figure 1 is a male, shell 25 mm long (coll. Schilder radula no. 2264), Figure 2 is a female, shell 23 mm long (radula no. 1115); we have drawn the first (. . . .) and the second (————) lateral only.

In *Staphylaea staphylaea* (LINNAEUS) the hook-shaped type has been observed in 33% (of 30 radulae), in *St. limacina* (LAMARCK) in 24% (of 38 radulae), in *St. semiplota* (MIGHELS) in one of the two slides preserved in coll. Gwatkin, British Museum (Natural History).

There is a distinct correlation between the two types of radula features and the sex of the animal though exceptions have been observed: in *Staphylaea staphylaea* the hook-shaped type was represented in no female, but in 7 males, and the slender type in 10 females and only in one male; in *St. limacina* these figures are 0, 6, 6, 4 respectively, so that the sum of both species can be tabulated as follows:

	females	males
hook-shaped	—	13
slender	16	5

In young specimens in which the sex cannot as yet be ascertained, the laterals always are of the slender type. In one evidently adult male *Staphylaea limacina* from Shimoni, Kenya (radula no. 870) the first formed anterior rows represent the slender type while the posterior rows (especially in the dark area) are hook-shaped: evidently there is a gradual changing from the slender type of the young stage to the hook-shaped teeth of the adult male. Besides, there are intermediates: some laterals of males are less broad though hook-shaped with obsolete denticles, whereas the females are less variable. However, there is no correlation between the laterals and the habitat, as in *St. staphylaea* from East Africa the hook-shaped and the slender labials are in 7 and 8, in the Pacific in 3 and 10 specimens respectively; in *St. limacina*

these figures are in East Africa 6 and 18, in the Pacific 3 and 9. There is also no correlation between the shape of the laterals and the smooth or tuberculate dorsum of the shells in *St. limacina.*

Another dimorphism exists in the absence or presence of basal denticles on the median in the radula of *Bistolida stolida* (Linnaeus). Usually the median is trapezoidal with the posterior surface smooth, but in some specimens two small denticles approximately in the center of the median have been observed: such a character surely could mislead taxonomists to treat it as a specific or even as a generic difference; in *B. stolida,* however, it is merely accidental. Among 24 radulae of *B. stolida* from various localities the central denticles of the median are absent in 18 specimens (Figure 3), but present in 6 (Figure 4),

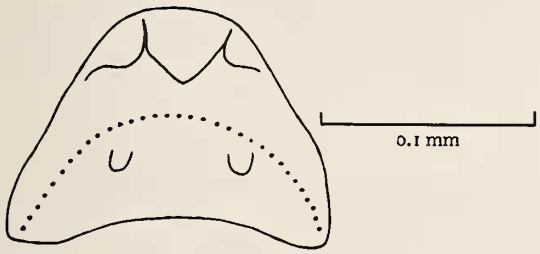

Figure 4

i. e. in a quarter of the examined radulae. Both figures represent female *B. stolida* from Shimoni, Kenya: Figure 3 is from an animal with a shell of 29 mm (radula no. 2070), Figure 4 from one with a shell of 32 mm (radula no. 1132). In this case there is no correlation to the sex of the animals as the number of smooth:denticulate medians is in females 8:3, in males 4:2; nor can regional differences be observed as the respective figures are in East African specimens 14:5, and in the Pacific 3:1.

In *Palmadusta asellus* (Linnaeus) similar differences occur: among the only three radulae which we could

Figure 5

examine, two are smooth like the figure given by Vayssière (1927, pl. 25, fig. 29), while the third exhibits two small central denticles in the medians along the entire radula ribbon (Figure 5); it belongs to a specimen from Namuka, Fiji, shell 12.4 mm long (radula no. 163).

Therefore taxonomists should be very careful in characterizing the radula of a species from one or only a few specimens. Besides we have learned that the obvious differences in the bursa copulatrix in the species of *Lyncina* Troschel, as shown by Kay (1963, figs. 6 a-f) are by no means to be regarded as specific; the dissection of hundreds of female *Lyncina* and other genera has shown that the features of the bursa copulatrix vary to a great extent, from total reduction to exceedingly complicated organs.

MONSTROSITIES

In previous papers (Schilder & Schilder 1963 a, etc.) we have shown that the number of radular rows, the size of the median, and the length of the radular ribbon (the two last named characters expressed in relation to the length of the shell) vary according to the usual random distribution; sexual differences and differences between various populations have been observed. There are, however, extreme variants which far exceed the natural limits of random distribution so that they must be classified as pathological abnormalities.

Thus, for instance, a female *Erosaria erosa* (Linnaeus) from Vatia Wharf, Fiji, shell 37 mm long, has a radula (radula no. 5358) unusually small, as there are only 78 rows, i. e. 6½ dozens (instead of 8 - 13) and the teeth are small; the index m/L, i. e. 200 times the breadth of the median (0.073 mm) divided by the length of the shell, is only 4 (instead of 5 to 13 in 418 radulae).

In a female *Cypraea tigris* Linnaeus from the same locality (shell 83 mm) the radula (radula no. 4995) is also small; it contains only 79 rows (i. e. less than 7 dozens instead of 11 to 18) and the teeth are much smaller than in other specimens, though they distinctly increase in size from the anterior rows to the nascentes in the rear; the breadth of the anterior medians is 0.112 mm, and 0.218 in the hindmost rows so that the diameter becomes almost double, and the index m/L increases from 3 to 5, but never attains the size of the median in normal specimens with equal rows, where it varies from 7 to 10 in 83 specimens. A male *C. tigris* from Lodoni, Fiji (shell 68 mm) shows a similar monstrosity of the radula (radula no. 3805); it contains 93 rows (8 dozen) only, the median is 0.147 mm broad in front rows, gradually increasing to 0.245 mm in posterior rows, i. e. the index m/L increases

from 4 to 7. In a female *Lyncina lynx* (Linnaeus) from Penrith Island, Queensland (shell 50 mm) the radula (radula no. 4025) exhibits only 111 rows (i.e. 9 dozens instead of 12 to 27), and the median increases from 0.152 to 0.180 mm (m/L increases from 6 to 7, almost attaining the normal size varying from 7 to 13 in 554 specimens). In a male *Mauritia eglantina* (Duclos) from Vatia Wharf, Fiji (shell 62 mm) the radula (radula no. 5116) exhibits 72 rows (i.e. 6 dozen instead of 7 to 17) and the median increases from 0.095 mm to 0.146 mm (m/L = 3 in front rows and 5 in the rear, on the lower limit of the normal variation from 4 to 12 in 638 specimens). All these radulae, extracted from quite normal animals, agree in the unusually small number of rows and in the small dimensions of the teeth, which gradually increase in size from the anterior rows to the rear, so that disease in early stages becomes gradually cured during the animal's life; but normal status never is regained.

Other monstrosities consist in the total absence of a kind of teeth along the whole radular ribbon; in a previous paper (Schilder 1963 c) we have figured the radula of *Monetaria annulus* (Linnaeus) from Shimoni, Kenya, in which the median is absent so that the admedians meet each other in all rows. In a male *Mauritia eglantina* (Duclos) from Lodoni, Fiji (shell 51 mm, radula no. 3729) the second lateral tooth is missing on one side of all rows, the first lateral is slightly removed from the admedian so that it replaces both laterals which are normally developed on the opposite side (Figure 6 shows a rather anterior row and a posterior row in the dark amber area); these two anomalies must have been caused before the beginning of the development of the radular teeth.

On the other hand, in a female *Lyncina lynx* from Vitilevu Bay, Fiji (41 mm) in the radula (no. 5293)

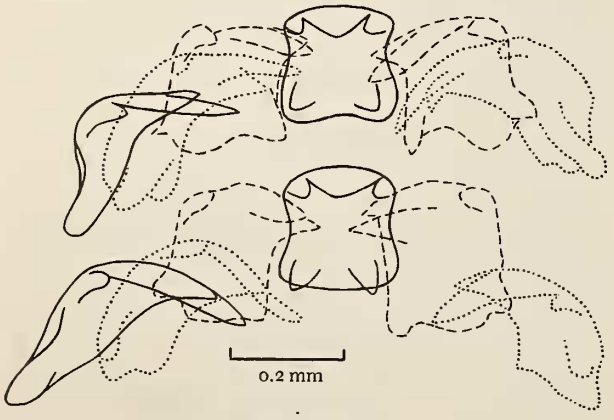

Figure 6

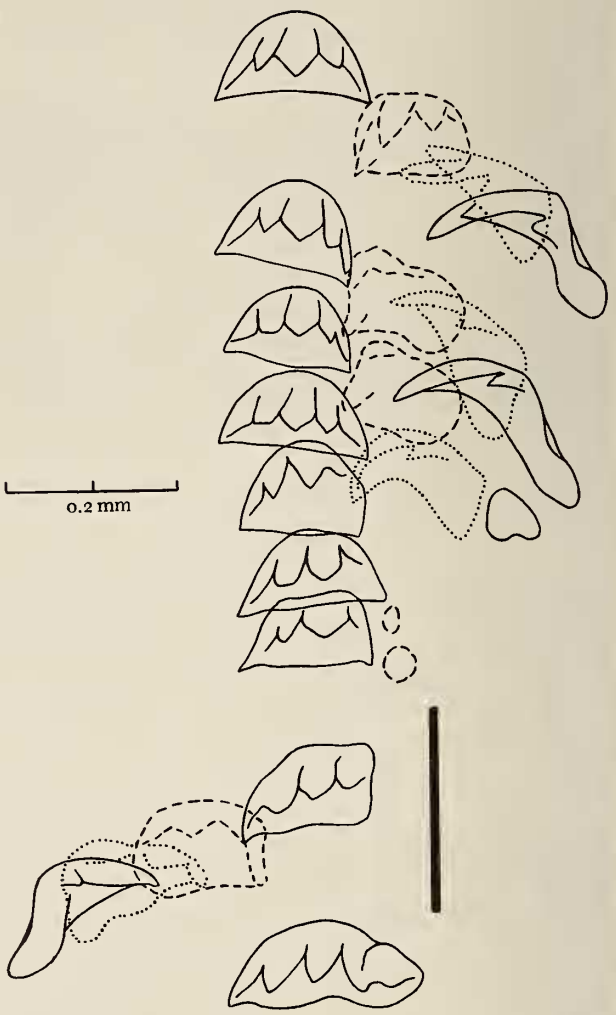

Figure 7

with 226 rows the monstrosity begins abruptly in the 149th row, in which the admedian of one side lacks its anterior cusps; in the 150th row, moreover, the laterals are displaced to the rear, and the second lateral is reduced to a small body; from the 151st row to the nascentes all admedians and laterals of this side are absent (small relics of the admedian in the 153rd to 155th row excepted), while these teeth are quite normal on the opposite side. Figure 7 shows the injured side of the still normal 146th row, the pathological 148th to 154th row, besides the 164th row with the lateral border of the band on which the teeth are fixed, and the 200th median with its thickened margin which can be observed as far as to the

nascentes. This anomaly may be caused by an injury of the animal in a later stage.

In a male *Lyncina lynx* from Lodoni, Fiji (28 mm) the radula (no. 3564) of which is pathologically short (111 rows, i. e. 9 dozens instead of 12 to 27), the median is split into two or three pieces which may coalesce in some rows, but never exhibit the typical features of the median. Figure 8 shows the 88th row with the three-parted median and with the admedian and laterals asymmetrically displaced which occurs the more if the median is dilacerate; the left column of enlarged medians represents nos. 19, 20, 21, and 29, the right column nos. 43, 62, 88 (see above), and a normal median of a *L. lynx* of the same sex, size, and habitat (radula no. 3563) for comparison. In this case, the normal formation of the medians has been disturbed from the beginning.

This monstrosity must not be confused with normal radulae the foremost rows of which are worn away by extraordinary use. So in a female *Erronea caurica* (Linnaeus) from Penrith Island, Queensland (34 mm, radula no. 4064) the anterior rows show the cusps of the teeth rather worn, and the second lateral reduced to a small relic, while the subsequent rows are quite normal; Figure 9 shows the third and the 50th row. Therefore we suspect

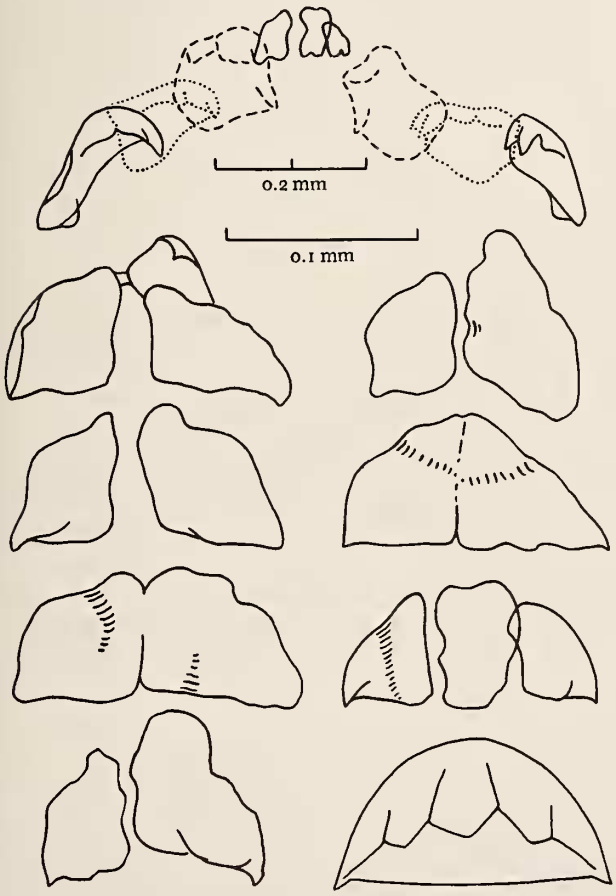

Figure 8

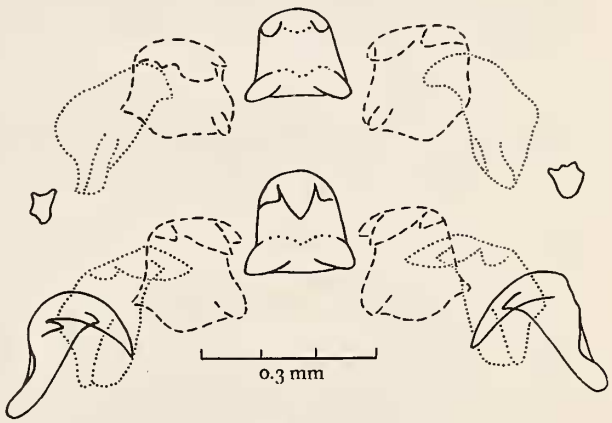

Figure 9

that the differences between *Lyncina carneola* (Linnaeus) and *L. leviathan* Schilder & Schilder shown by Kay (1961; 1963, pl. 8, figs. 8, 9) may be established on very aged *L. leviathan* with worn radular teeth, because we could not discover any difference between the radula of large adult males of *L. leviathan* from Hawaii (radula nos. 696, 5717) and those of *L. carneola* from the Indo-Pacific and *L. titan* Schilder & Schilder from East Africa; moreover Kay (1963, p. 52) admits that in juvenile *L. leviathan* the outer laterals look like those in *L. carneola.*

In some specimens two outer lateral teeth accidentally are confluent longitudinally at one side, as it is in rather posterior rows of *Lyncina lynx* from Vuda Point, Fiji (female, 42 mm, radula no. 4915, see Figure 10) and in two *L. vitellus* (Linnaeus) from the same locality; Figure 11 represents a female (45 mm, radula no. 4945), Figure 12 a male (45 mm, radula no. 4950).

This longitudinal confluence of the second laterals can be accompanied by a duplication of the laterals in a row, so that in three consecutive rows there are three medians and three admedians, but four inner laterals and four outer laterals on one side of the radula; this fact has been observed in a female *Lyncina lynx,* also from Vuda Point, Fiji, where such abnormalities seem to be relatively frequent (39 mm, radula no. 5248); Figure 13

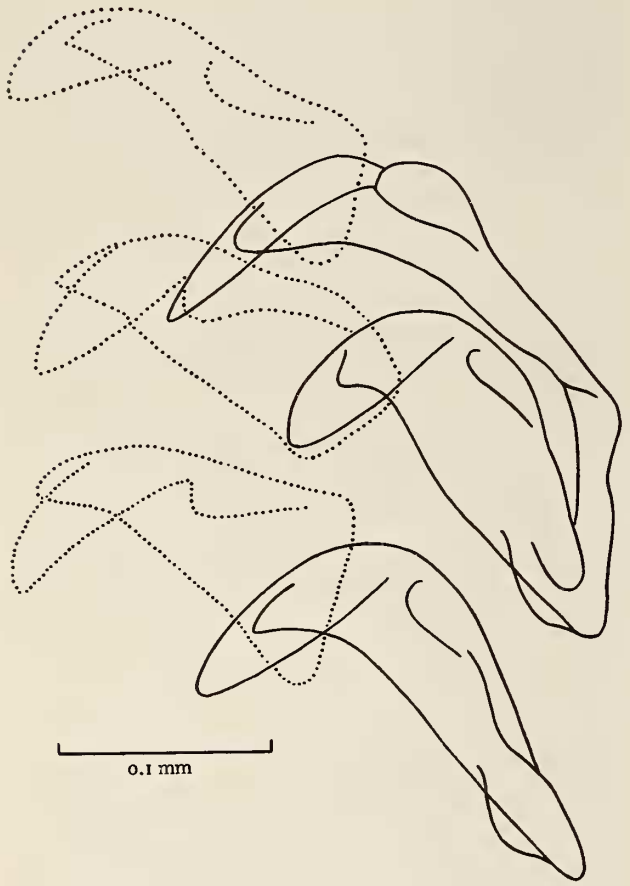

Figure 10

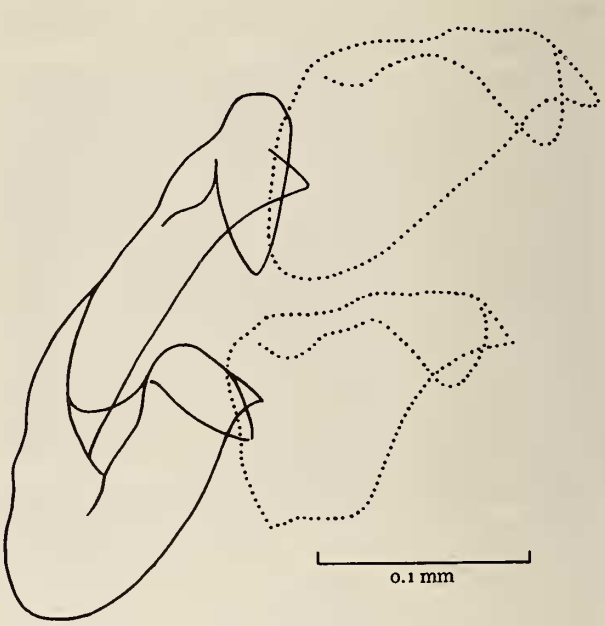

Figure 11

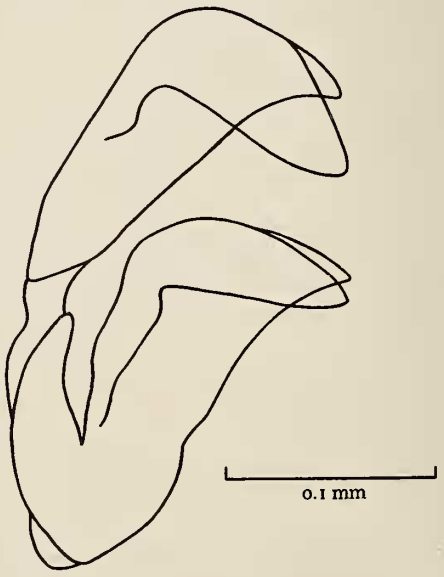

Figure 12

shows a hole behind the first figured row, then both laterals of the second row duplicated, and the posterior second lateral of this row united with that of the third row.

In contrast to this longitudinal duplication there exists also a transverse one, which has been figured by PEILE (1937; see also SCHILDER, 1963 c, p. 129, note) in *Erosaria caputserpentis* (LINNAEUS).

In addition to absence, coalescence, and duplication of radular teeth there occurs a fourth tendency to monstrosities: enlargement of a tooth on one side of all rows. In a female *Mauritia eglantina* from Nananu-i-Ra, Fiji (51 mm, radula no. 5176) the right admedian is almost three times as broad as the opposite one, pressing the median to the left so that the latter becomes asymmetrically skewed and the tips of the laterals are widely separated instead of meeting each other in the center of the median; there is a short, shallow, longitudinal rim starting from the posterior margin of the giant admedian, and the right second lateral shows no inner denticle.

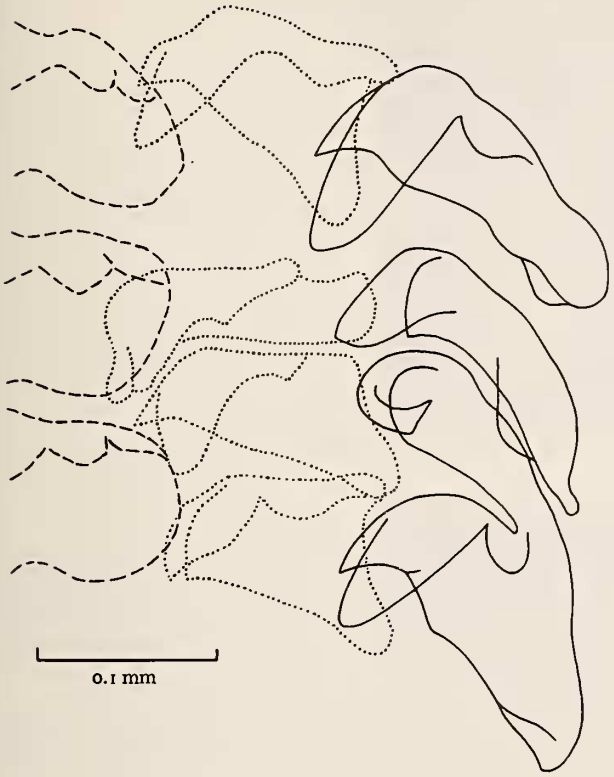

Figure 13

Figure 14 shows this curious monstrosity which is identical in all rows of this unique radula.

ADDITIONAL REMARKS

1. In many male specimens of various cowrie species the penis is apparently stunted; it is at most half as long as the normal penis is, and strongly club-shaped at its top; in some adult specimens the penis is still short and thin as it is in very juvenile (oliviform) specimens, while in an adult *Monetaria annulus* it is solid, but S-shaped and only 2 mm long instead of 9 to 14 mm as in normal males.

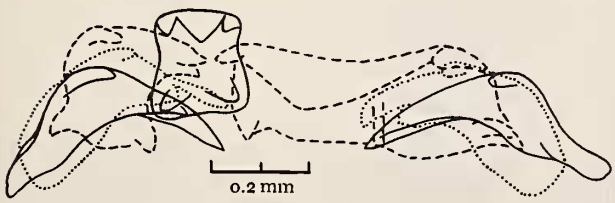

Figure 14

A *Cypraea tigris* shows a penis of almost normal size, but with two short tips separated by the usual longitudinal rim; however, we did not observe a monstrosity such as has been figured for *Lyncina carneola* by VAYSSIÈRE (1923, pl. 3, fig. 28).

2. We have observed that in specimens the shell of which is at least partially covered by a green layer of enamel (*Lyncina carneola*) or with enclosed particles of mud (*L. vitellus*) the general color of the animal preserved in alcohol is distinctly green; but this unusual color of the animal has also been observed in two *L. lynx*, the shells of which do not exhibit unusual features.

3. Many monstrosities of the cowrie shells have been systematically arranged, described, and figured by SCHILDER, 1930.

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